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Science Literacy and Self-Regulated Learning on Students' Critical Thinking Skills in Science Learning in Elementary School

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Abstract

This study aims to examine the influence of science literacy and self-regulated learning on the critical thinking ability of elementary school students in Natural Sciences (IPA) learning. In an era marked by technological developments and the complexity of global problems, students are not only required to master scientific concepts, but also to be able to think critically and manage their learning process independently. This study highlights the relationship and influence of these two variables on the critical thinking skills of elementary school students in the context of science learning. Empirical evidence suggests that high levels of science literacy contribute positively to critical thinking skills, while self-regulated learning plays an important role in helping students regulate their cognitive and metacognitive processes. By involving elementary school students in science learning, this study seeks to explain how the relationship between science literacy and self-regulation in supporting the development of critical thinking skills. The results of the research are expected to provide implications for teachers and curriculum designers in designing learning that fosters critical thinking skills through strengthening science literacy and self-regulated learning.

Keywords: critical thinking, science literacy, self-regulation, science learning, elementary school.

1 INTRODUCTION

Critical thinking skills are one of the 21st century skills that elementary school students must have in facing the challenges of modern life. In the context of science learning, critical thinking not only means being able to answer scientific questions, but also understanding concepts in depth, relating to real phenomena, and evaluating scientific information rationally (Janoušková et al., 2023). Meanwhile, *Science Literacy* It is defined as the ability to understand scientific concepts, identify questions, and draw conclusions based on evidence to make decisions relevant to daily life (Lederman et al., 2023).

Result *Programme for International Student Assessment (PISA)* 2022 shows that the science literacy scores of Indonesian students are still below the OECD average (Teig et al., 2022), The low level of science literacy shows that students do not fully have adequate scientific and critical thinking skills (Suwono et al., 2023). One of the factors that affect this condition is the low ability of students to manage their own learning process (*self-regulated learning*) which includes aspects of motivation, learning strategies, and emotional control (Schunk & Zimmerman, 2022). *Self-regulated learning* (SRL) is the ability of students to set learning goals, choose appropriate strategies, monitor the learning process, and reflect on the results obtained (Radović et al., 2024).

Based on the results of initial observations at SDN Jatinegara 06 and SDN Jatinegara 15 Pagi, information was obtained that most students still showed limitations in critical thinking skills and self-regulation when learning science. Students tend to wait for the teacher's direction, rarely ask questions, and are not used to reflecting on the results of

the experiment. Teachers admit that in learning activities, students focus more on completing written assignments rather than understanding the meaning of scientific concepts in depth. Interviews with science teachers show that some students still have difficulty in designing simple experiments, interpreting data, and connecting science phenomena to daily life. This emphasizes that students' science literacy and SRL skills still need to be improved in order to support their critical thinking skills.

Previous studies have shown a strong relationship between science literacy and critical thinking skills. Fortus et al. (2022) found that science literacy has a significant positive correlation with the critical thinking skills of elementary school students. Similar results were also shown by the study (Kumar et al., 2023) that *self-regulated learning* has a direct effect on students' critical thinking skills and academic achievement. However, there is still limited research that simultaneously examines the influence of science literacy and self-regulation on critical thinking skills in the context of science learning in Indonesian elementary schools.

Theoretically, this research is expected to contribute to the development of education, especially in understanding the role of science literacy and SRL in the formation of critical thinking skills at the basic education level. Practically, the results of the research can be the basis for elementary school science teachers in designing learning strategies that foster learning independence and stimulate students' critical thinking through a science literacy approach. Thus, strengthening these two aspects can be an effective strategy in forming a generation that thinks scientifically, reflectively, and adaptively to the development of the times.

1. Does science literacy have a direct effect on students' critical thinking skills in science learning in elementary school?
2. Does *self-regulated learning* have a direct effect on students' critical thinking skills in science learning in elementary schools?
3. Does science literacy have a direct effect on students' *self-regulated learning* in science learning in elementary schools?
4. Does science literacy have an indirect effect on critical thinking skills through *self-regulated learning* of students in science learning in elementary school?

2 RESEARCH METHODS

This study uses a quantitative approach with a design *explanatory research* through the path analysis technique (*path analysis*) (Sharma et al., 2023), which aims to test for direct and indirect influences *Science Literacy* (X_1) and *self-regulated learning* (X_2) against *Critical thinking skills* (Y) Elementary school students. This approach was chosen because it is able to explain the causal relationship between variables while assessing their influence strength (Tang et al., 2023).

The study was conducted on grade V students from 2 public elementary schools in East Jakarta, with a total of 120 students. Sampling technique using *cluster random sampling* to represent the condition of schools in urban areas. The data collection technique uses tests and questionnaires as well as research instruments on each variable are presented in the following table:

Table 1. Science Literacy Indicators

No.	Science Literacy Indicators	Operational Description (Observed Behavior)
1.	Scientific Concept Understanding	Students are able to explain natural phenomena.
2.	Ability to conduct scientific inquiry (Scientific Inquiry Skill)	Students are able to design and execute simple research, observe, record results, and draw conclusions based on evidence.

No.	Science Literacy Indicators	Operational Description (Observed Behavior)
3.	Ability to interpret data and scientific evidence (Evidence Interpretation)	Students are able to relate data to concepts, and make logical conclusions.
4.	Science Application in Daily Life	Students are able to explain events in the surrounding environment and make informed decisions.
5.	Scientific Attitude to Science and the Environment	Students show curiosity, are open to new evidence, think critically, and care about environmental and technological impacts.

Table 2. Self Regulated Learning Indicators

No.	Indikator Self-Regulated Learning	Operational Description (Observed Behavior)
1.	Goal Setting & Planning	Students are able to determine learning goals, make a plan for learning activities.
2.	Cognitive & Metacognitive Regulation	Students are able to choose and apply learning strategies, monitoring their understanding during the learning process.
3.	Motivational Regulation	Students have an internal drive to learn, are able to maintain enthusiasm and focus, manage emotions.
4.	Behavioral & Environmental Regulation	Students are able to manage their learning time, arrange the learning environment
5.	Self-Evaluation and Reflection	Students are able to assess their learning progress, identify weaknesses and strengths.

Table. 3. Critical Thinking Indicators

No.	Critical Thinking Indicators	Operational Description (Observed Behavior)
1.	Providing Elementary Clarification	Students are able to identify problems, ask relevant questions.
2.	Providing Advanced Clarification	Students are able to connect scientific concepts, explaining the cause-and-effect relationship of natural phenomena.
3.	Determining Strategies and Techniques for Solving Problems (Strategies and Tactics)	Students are able to choose the right strategies to investigate problems.
4.	Inference & Evaluation	Students are able to draw conclusions based on empirical evidence, distinguishing between facts and opinions.
5.	Creating and Developing New Ideas (Creation & Reflection)	Students are able to pour out new ideas, design alternative solutions, and create simple works.

The data analysis technique uses path analysis, path analysis is carried out to test two main relationships: 1) The direct influence of science literacy on critical thinking skills; 2)

The indirect influence of science literacy on critical thinking skills through the mediation of *self-regulated learning*; 3) Good model criteria are based on *goodness of fit indices*.

3 RESULT AND DISCUSSION

3.1 Statistics Descriptive

To obtain an initial overview of the distribution of research data, descriptive statistical analysis was carried out on three main variables, namely Self-Regulated Learning (SRL), Science Literacy, and Critical Thinking Ability. This analysis included the amount of data, mean values, medians, standard deviations, minimum and maximum values, and Shapiro–Wilk normality tests. These descriptive results aim to ascertain the characteristics of the data that will be used in further analysis through path analysis. The summary of descriptive statistics is presented in the following table.

Table 4. Write a short caption on top of the table

	SRL_SelfRegulatedLearning	LS_LiterasiSains	BK_BerpikirKritis
N	120	120	120
Missing	0	0	0
Mean	67.4	68.2	87.8
Median	67.0	69.5	89.5
Standard deviation	8.10	8.17	6.36
Minimum	50	47	60
Maximum	89	83	99
Shapiro-Wilk W	0.976	0.970	0.869
Shapiro-Wilk p	0.029	0.009	<.001

Based on the descriptive statistical table, all variables have a complete amount of data (N = 120) without any missing values. The average scores of SRL, Science Literacy, and Critical Thinking are in the fairly high category with a relatively homogeneous distribution of data, as shown by the standard values of the deviation that is not too large. However, the results of the Shapiro–Wilk normality test showed that all three variables had a p< value of 0.05, which means that the data were not normally distributed.

3.2 Uji Hypothesis

After estimating the path analysis model, the next step is to evaluate the contribution of each endogenous variable through the value of the determination coefficient (R^2) and test the significance of the model using Wald Chi-Square. The R^2 value provides information about how much variance of endogenous variables can be explained by predictive variables in the model. A summary of the test results is presented in the following table.

Table 5. R2 Value

		95% Confidence Intervals				
Variable	**R^2**	**Lower**	**Upper**	**Wald X^2**	**df**	**p**
BK_BerpikirKritis	0.0331	0.000	0.122	4.10	1	0.043
SRL_SelfRegulatedLearning	0.0362	0.000	0.128	4.51	1	0.034

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Based on the table, the Critical Thinking variable (BK_BerpikirKritis) has an R^2 value of 0.0331, which shows that the model is able to explain about 3.31% of the variation in students' critical thinking ability. The Wald Chi-Square value of 4.10 with a p-value of 0.043 indicates that the relationship model to this variable is significant at the 95% confidence level.

Table 5. Estimated value

				95% Confidence Intervals						
Variable 1	Variable 2	Estimate	SE	Lower	Upper	β	z	p	Method	Type
BK_BerpikirKritis	BK_BerpikirKritis	38.8	5.00	28.9	48.6	0.967	7.75	<.001	Estim	Residuals
SRL_SelfRegulatedLearning	SRL_SelfRegulatedLearning	62.7	8.09	46.8	78.5	0.964	7.75	<.001	Estim	Residuals
LS_LiterasiSains	LS_LiterasiSains	66.1	0.00	66.1	66.1	1.000			Sample	Variables

Based on the table of analysis results, there are three main variables that are reviewed, namely Critical Thinking (BK), Self-Regulated Learning (SRL), and Science Literacy (LS). The estimated value of students' critical thinking ability is 38.8 with a standard error of 5.00 and a 95% confidence interval in the range of 28.9 to 48.6. The β value of 0.967 and the z-value of 7.75 with p <.001 indicate that this estimate is very significant and that the model has a high level of accuracy in predicting these variables. In the Self-Regulated Learning variable, the average estimated value was 62.7 with a standard error of 8.09 and a confidence interval of 46.8 to 78.5. The values of β = 0.964, z = 7.75, and p <.001 indicate that the SRL is also significant and the estimate is very strong despite the greater variation in the data. Meanwhile, the Science Literacy variable had an estimated value of 66.1 with a standard error of 0.00 and an unchanged confidence interval (66.1–66.1), indicating that this value was derived from direct sample data. A value of β = 1,000 confirms that this variable is an actual measurement with no model estimates. Overall, the three variables showed high and significant values, and the statistical model was able to provide excellent estimates for both the residual variables and the sample variables. The following diagram shows a path analysis model that illustrates the direction and strength of the relationship between Science Literacy (LS), Self-Regulated Learning (SRL), and Critical Thinking (BK). The coefficients on each arrow indicate the magnitude of the influence between variables.

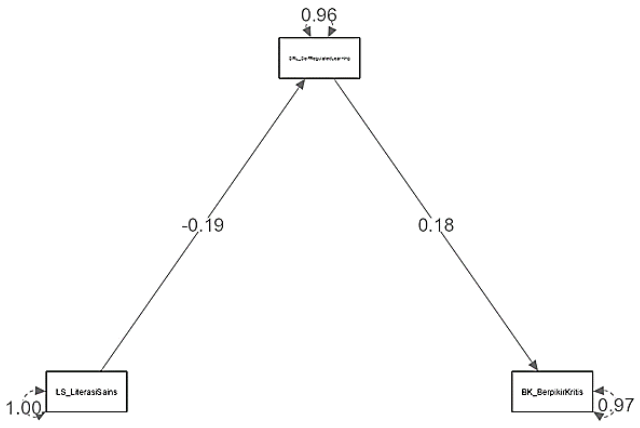


Figure 1. Path Diagram of Science Literacy, SLR and Critical Thinking

The results of the model showed that SRL had a positive effect on Critical Thinking (0.18), so that the better the student's self-regulation, the higher their critical thinking ability. Meanwhile, Science Literacy had a small negative effect on SRL (-0.19). In general, SRL is a stronger factor in influencing critical thinking skills than Science Literacy.

3.3 Discussion

The results of the study show that *self-regulated learning* (SRL) has a significant contribution to students' critical thinking skills in science learning in elementary school. When viewed from the SRL indicator, students' ability to plan learning goals, regulate cognitive and metacognitive processes, manage motivation, regulate behavior and learning environment, and conduct self-evaluation and reflection has proven to play an important role in improving critical thinking skills. These findings are consistent with Dökmecioğlu et al. (2022) which confirms that self-regulation is a strong predictor of higher-level thinking skills in the context of science learning. When students are able to monitor their understanding, determine the right learning strategies, and evaluate the learning process, they are better prepared to carry out critical thinking activities such as providing simple explanations, connecting scientific concepts, choosing problem-solving strategies, evaluating evidence, and creating new ideas. In line with Zeidner & Stoeger (2019), strong SRL abilities encourage students to think more analytically, reflectively, and be able to solve scientific problems systematically.

On the other hand, science literacy does not show a strong direct influence on students' critical thinking abilities. However, its influence is still visible through indirect channels through SRL. When viewed based on the indicators, science literacy includes understanding scientific concepts, the ability to conduct scientific investigations, interpreting evidence, applying science in daily life, and demonstrating scientific attitudes such as curiosity and openness to evidence. These indicators actually provide a solid foundation for critical thinking skills. However, as explained Demircioglu et al. (2023); Yeh (2009), understanding scientific concepts alone is not enough to improve critical thinking skills if students are not able to integrate that knowledge into a directed and independent learning process. The findings of this study show a similar pattern: students with high science knowledge do not necessarily have good SRL skills, as shown by the small negative influence of science literacy on SRL (−0.19). These findings are in line with Martin-Alguacil et al. (2024) who report that science learning that overemphasizes memorizing concepts often makes students less trained to use self-study and self-evaluation strategies.

When the indirect relationship is examined, it can be seen that science literacy has a contribution to the ability to think critically through SRL. This happens because science literacy indicators such as the ability to conduct scientific investigations, interpret data and evidence, and apply concepts in daily life can encourage students to plan, choose strategies, and reflect like a self-regulation process. This is where SRL plays an important role as a bridge between the understanding of science and the critical thinking process, especially in the aspects of further explanation, evidence evaluation, and formulation of problem-solving strategies that are the core indicators of critical thinking ability.

Overall, the results of this study strengthen the view that SRL is a key variable that links science literacy with critical thinking skills. Science learning that only emphasizes mastery of scientific concepts is not enough to develop critical thinking skills without the integration of self-regulation skills. Therefore, science learning needs to be designed to build student learning independence through inquiry activities, experiments that provide space for scientific inquiry, data interpretation exercises, self-reflection, and the provision of formative feedback. The integration of science literacy and SRL indicators in learning is expected to improve students' ability to provide simple to complex explanations, formulate strategies, evaluate evidence, and create creative solutions in solving scientific problems.

4 CONCLUSION

Based on the results of the path analysis carried out, it can be concluded that science literacy does not have a significant direct influence on students' critical thinking skills in science learning in elementary schools. These findings show that mastery of concepts and scientific knowledge is not enough to improve critical thinking skills without support from other aspects, especially self-regulation of learning. On the other hand, self-regulated learning has been shown to have a direct and significant effect on critical thinking skills, so students who are able to plan, monitor, and evaluate their learning process tend to have better critical thinking skills. In addition, science literacy was found to have a direct effect on self-regulated learning, albeit with relatively small influence, suggesting that understanding science can help students in setting learning strategies but is not a dominant factor. Furthermore, science literacy has an indirect effect on critical thinking skills through the mediation of self-regulated learning, which means that science literacy will have a positive impact on critical thinking skills if students have good self-regulation skills

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